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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This test operations procedure (TOP) presents test methods to evaluate the technical performance of heading reference systems that meet criteria specified in applicable required documents. New universal heading reference systems are continually being developed and improved to meet new and existing requirements, with an all weather capability, for military and commercial aircraft. The heading reference system provides an accurate determination of aircraft heading (cont)

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relative to true north. This is accomplished by use of a magnetic compass and/or a gyro compass, depending on the region of operation. Engineers and other personnel engaged in testing and evaluating aircraft systems have developed certain procedures of testing over a long period of time. These procedures, properly used, can aid in determining the acceptability of heading reference systems for an intended use. The reference system must adhere to user (Government) and manufacturer's specification to be accepted. This TOP is limited to heading reference sytems of the directional gyro type.

US ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

DRSTE-RP-702-105 20 May 1983
Test Operations Procedure 6-2-120
AD No. A130285

ATTITUDE AND HEADING REFERENCE SYSTEMS

1.0 SCOPE. This test operations procedure (TOP) presents test methods to evaluate the technical performance of heading reference systems that meet criteria specified in applicable required documents. (Qualitative Materiel Requirements (QMR) and Small Development Requirements (SDR)

a. New universal heading reference systems are continually being developed and improved to meet new and existing requirements, with an all weather capability in applications where a precision heading reference is required for use in conjunction with navigation systems such as doppler etc, for military aircraft. The heading reference system provides an accurate determination of aircraft heading relative to true north. This is accomplished by use of a magnetic compass and/or a gyro compass, depending on the region of operation.

b. Engineers and other personnel engaged in testing and evaluating aircraft systems have developed certain procedures of testing over a long period of time. These procedures, properly used, can aid in determining the acceptability of heading reference systems for an intended use. The reference system must adhere to user (Government) and manufacturer's specification to be accepted.

c. This TOP is limited to heading reference systems of the directional gyro type.

2.0 FACILITIES AND INSTRUMENTATION. The test item shall be placed in operating condition as outlined in the equipment technical manual.

2.1 Facilities. A bench test facility with power supply and a target resolution range equipped with a simulated azimuth detector and a Scorsby Table.

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*This TOP supersedes MTP 6-2-120, 1 February 1968.

2.2 Instrumentation and Equipment. The following instrumentation and equipment shall provide adequate tolerances and technical characteristics in conducting the specific tests listed below: Precise angle indicator, simulated azimuth detector (Clifton Synchro Transmitter type CGH-11-B-2, or equal), Ammeter (DC), VTVM (DC), Frequency meter, Voltmeter. Power meter, Cameras, Dual-Trace pen recorder, and Scorsby Table (Ideal Aerosmith Part No. 1412, or equal).

2.3 Test Parameters.

a. Radio Frequency Interference - Determine the susceptibility of the test item to electromagnetic radiation from other equipment. The measurements shall be performed in accordance with the procedures given in MIL-STD-461, 462, and 463.

b. Low-Strength, Earth-Magnetic-Field Enviornment - Determine system error when the system is operating in a strong earth-magnetic-field environment. A simulated azimuth detector connected to the system shall be oscillated to a predetermined amount on either side of a synchronized null. The oscillator excitation shall be reduced to represent predetermined horizontal field strengths.

c. Voltage and Frequency Variation - Determine if the test item will operate satisfactorily during voltage and frequency extremes. Satisfactory operation of the test item during voltage and frequency extremes shall be determined by connecting the test item to a simulated azimuth detector and setting it to a synchronized null at a 0-degree heading. Voltage and frequency extremes shall be applied, and the test item shall be resynchronized at each value.

d. Erection Cycle and Accuracy - Determine the initial erection capabilities of the vertical gyroscope. The initial erection capabilities of the vertical gyroscope are determined by mounting the test item on a Scorsby Table, aligning the gyroscope in pitch and roll, and subjecting the test item to the Scorsby Table motion.

e. Heading Drift Rate - Determine the heading drift rate of the vertical gyroscope. The heading drift rate of the vertical gyroscope shall be determined by mounting the test item on a Scorsby Table and connecting a precise angle indicator to the heading output of the gyroscope. The difference in initial heading and heading after a predetermined time interval shall be observed.

f. Vertical Drift Rate - Determine the vertical drift rate in pitch and roll of the vertical gyroscope. The vertical drift rate of the vertical rate gyroscope shall be determined by mounting the test item on a Scorsby Table and connecting a precise angle indicator to the heading output of the gyroscope. The difference in initial heading and heading after a predetermined time interval shall be observed.

g. Heading Precession Rate - Determine if the north/south latitude correction circuitry is capable of correcting for the apparent drift gyroscope due to the earth's rotation. The heading precession rate shall be determined by mounting the test item on a Scorsby Table, connecting a precise angle indicator, and applying a known current to the north and south latitude control circuits, and determining the rate of heading change during a time interval.

h. Compass Mode Accuracy - Determine the accuracy of the test item when operated as an undamped magnetic compass slaved to the magnetic azimuth detector. The test item shall be operated as an undamped magnetic compass slaved to a magnetic azimuth detector.

i. Compass Air Swing - Determine the compass error in free and slaved modes under flight conditions. This subtest consists of evaluating the test item under actual flight conditions. The compass error, while the test item is in the free and slaved modes, shall be determined.

j. Compass Ground Swing Calibration - Align and compensate compass system index and magnetic errors. This subtest will evaluate the host vehicle installed gyromagnetic compass accuracy of the test item, fully operational in a magnetically clean ground environment (e.g. surveyed compass rose). The compass ground swing may be accomplished IAW MIL-STD-765 using any one of the four following procedures:

1. Sitting compass
2. Magnetic method using a survey transit and compass rose.
3. Electronic method using an MC-1 magnetic compass calibration set.
4. M2A2 aiming circle using the compass swing method (for test items installed in aircraft equipped with doppler radar navigation systems.

3.0 PREPARATION OF TEST

3.1 Facilities. Assure facilities are available.

3.2 Equipment assemble instrumentation and the test item to conform with instructions that follow.

3.3 Record the following:

a. Nomenclature serial number(s), and manufacturer's name of the test item.

b. Nomenclature serial number, accuracy tolerances, calibration requirements, and last calibration date of the electronic test equipment selected for the tests.

4.0 TEST CONTROLS

a. Select test equipment having an accuracy of at least 10 times greater than that of the function to be measured.

b. Ensure that all test personnel are familiar with the required technical and operational characteristics of the item under test, such as stipulated in the QMR, SDR, and TC documents.

c. Review all instruction material issued with the test item by the manufacturer, contractor, or Government, as well as reports of previous tests conducted on the same types of equipment, and familiarize all test personnel with the contents of such documents. These documents shall be kept readily available for reference.

d. Inspect the test item thoroughly for obvious physical and electrical defects such as cracked or broken parts, loose connections, bare or broken wire, loose assemblies, bent relay and switch springs, and corroded plugs and jacks. All defects shall be noted and corrected before proceeding with the tests.

e. Prepare record forms for systematic entry of data, chronology of tests, and analysis in final evaluation of the test item.

f. Prepare adequate safety precautions to provide safety for personnel and equipment, and ensure that all safety SOPs are observed throughout the test.

5.0 PERFORMANCE TESTS

NOTE: Modifications of these procedures shall be made as required by technical design of the test item and availability of test equipment, but only to the extent that such modified procedures will not affect the validity of the test results.

5.1 Radio Frequency Interference Tests

Subject the item under test to radio frequency measurements in accordance with the procedures given in MIL-STD-461, 462, and 463.

5.2 Low-Strength, Earth-Magnetic-Field Environment Tests

a. Connect the test item to a simulated azimuth detector.

b. Apply power and synchronize the null of the test item with the null of the simulated azimuth detector.

c. Reduce the excitation of the simulated azimuth detector to represent a horizontal field strength of 0.080 $\pm$ 0.002 oersted.

d. Record the excitation of the simulated azimuth detector.

e. Oscillate the simulated azimuth detector through either side of null at approximately 6 cycles per minute.

f. Record number of degrees of simulated azimuth detector oscillation on each side of null.

g. Observe the system's heading initially and at one minute intervals after start of oscillation until three consecutive readings are within 0.1 degree of each other.

h. Record system's initial heading and heading at 1-minute intervals until end of test.

i. Repeat steps b through h above, on three headings not less than 60 degrees apart.

5.3 Voltage and Frequency Variations Tests IAW Equipment specifications and MIL-STD-704 Limitations.

a. Connect the test item to a simulated azimuth detector.

b. Set the simulated azimuth detector at a 0-degree heading.

c. Apply power and synchronize the null of the test item with the null of the simulated azimuth detector.

d. Apply voltage extremes and resynchronize the test item at each extreme. Record applied voltage extremes.

e. Note and record the shift in synchronized null for each voltage extreme.

f. Apply frequency extremes and resynchronize the test item at each extreme. Record applied frequency extremes.

g. Note and record the shift in synchronized null for each frequency extreme.

5.4 Erection Cycle and Accuracy Tests

a. Mount the test item on a Scorsby Table and connect a dual-trace pen recorder to monitor the movement of the table. Connect a precision angle indicator to the system roll and pitch outputs.

b. Align the gyroscope in pitch and roll to a predetermined position and tolerance.

c. Record the gyroscope position and tolerances.

d. Apply power to the test item and the Scorsby Table, and energize the dual-trace recorder.

NOTE: The Scorsby Table shall make an excursion about each axis of $\pm$ 1 to 1/2 degree at 5 to 7 cycles per minute with motion reversal once each minute.

e. Measure and record the time completion of erection and the average pitch and roll excursions.

f. Turn off the Scorsby Table power and tilt the gyroscope 30 degrees nose up and 30 degrees right roll.

g. Repeat steps d and e above.

h. Reduce the applied voltage to the test item to a predetermined level and repeat steps b through g above.

i. Repeat f and g to verify maximum angular limits and accuracy (e.g., ± 90 deg.)

5.5 Heading Drift Rate Tests

a. Mount the test item on a Scorsby Table.

b. Connect a precise angle indicator to the gyroscope's heading output.

c. Apply power to the test item and the Scorsby Table.

d. Measure and record the initial heading as indicated by the precise angle indicator, and at 5-minute intervals for a total running time of 3 hours. Provide an operating/observation time of 1 hour to measure normal/abnormal drift characteristics followed by the procedure described in "g" below.

e. Record time of readings and local latitude.

g. Repeat steps c, d, and e above, three times or until the time to reach a steady drift rate has been determined.

5.6 Vertical Drift Rate Tests

a. Mount the test item on a Scorsby Table.

b. Connect a precise angle indicator to the gyroscope's pitch output.

c. Apply power to the test item and the Scorsby Table.

d. Measure and record the initial pitch attitude as indicated by the precise angle indicator, and at the end of a 15-minute time interval.

NOTE: The time interval may be extended to 1 hour or more, as required, with observations recorded every 15 minutes. In any event, the time to reach a steady state drift rate shall be determined.

e. Record time of readings and local latitude.

f. Turn off power to the Scorsby Table and test item.

g. Disconnect the precise angle indicator from the gyroscope's pitch output and connect it to the gyroscope's roll output.

h. Apply power to the test item and the Scorsby Table.

i. Measure and record the initial roll attitude as indicated by the precise angle indicator, and at the end of a 15-minute time interval. (See note above.)

j. Repeat steps e and f above.

5.7 Heading Precession Rate Tests

a. Mount the test item on a Scorsby Table.

b. Connect a precise angle indicator to the item under test.

c. Energize the test item and apply a known current (ma dc) to the north latitude control circuit. Record the applied dc current.

d. Measure and record the rate of heading change, as indicated by the precise angle indicator, during specified time interval. Record the elapsed time of the test.

e. Disconnect the dc input from the north latitude control circuit and apply a known current (ma dc) to the south latitude control circuit. Record the applied dc current.

d. Measure and record the rate of heading change during specified time interval.

e. Record the elapsed time of the test and the local latitude.

5.8 Compass Mode Accuracy Tests

a. Connect a precise angle indicator to the heading output of the item under test.

b. Set the test item to compass mode and the latitude control to 0 degrees.

c. Rotate the azimuth detector clockwise in 30-degree increments from 0 degrees through 360 degrees.

d. Measure and record the heading indicator readout for each 30-degree increment.

e. Repeat steps b, c, and d above, rotating the azimuth detector counterclockwise.

f. If this test shows that there is a ground swing and boresight misalignment that causes consistent errors, then a ground swing and boresight alignment will need to be performed. (This can be done by the manufacturer or the installation maintenance contractors)

5.9 Compass Air swing Tests (Photographic and Stable Platform Methods)

5.9.1 Photographic Method - Preparation for Test

a. The test officer shall schedule this test in accordance with the availability of the target resolution range.

b. The pilot of the test aircraft shall be thoroughly briefed to familiarize him completely with the test objectives and flight patterns required over the target resolution range.

c. The number of practice flights made shall be sufficient to satisfy the test officer that the pilot can execute a long, stabilized approach.

d. The types of cameras to be utilized shall be determined by personnel in the Photographic Laboratory Section. The types of film shall be specified and issued by these personnel.

e. The test officer shall insure that the cameras are properly installed and equippped with shock-mounts to minimize vibration effects.

f. The camera photographing the target resolution range shall be of a type to compensate for the relative motion between the aircraft and the target.

5.9.2 Photographic Method - Conduct of Test

a. Install the test item in the panel of the test aircraft.

b. Mount a photopanel camera to photograph the heading roll and pitch outputs of the test item.

c. Mount a second down looking camera to photograph the ground target resolution range from the aircraft. Synchronize both cameras.

d. Fly the aircraft at the specified speed and at an altitude of approximately 1000 feet, over a target resolution range, following the pattern shown in figure 1.

e. As the test item is flown over the target resolution range, simultaneously photograph the compass system readout and the ground target.

NOTE: The cameras shall be started 2 seconds before the aircraft is over the target and shall be run at a predetermined speed until the aircraft has flown 2 seconds beyond the target.

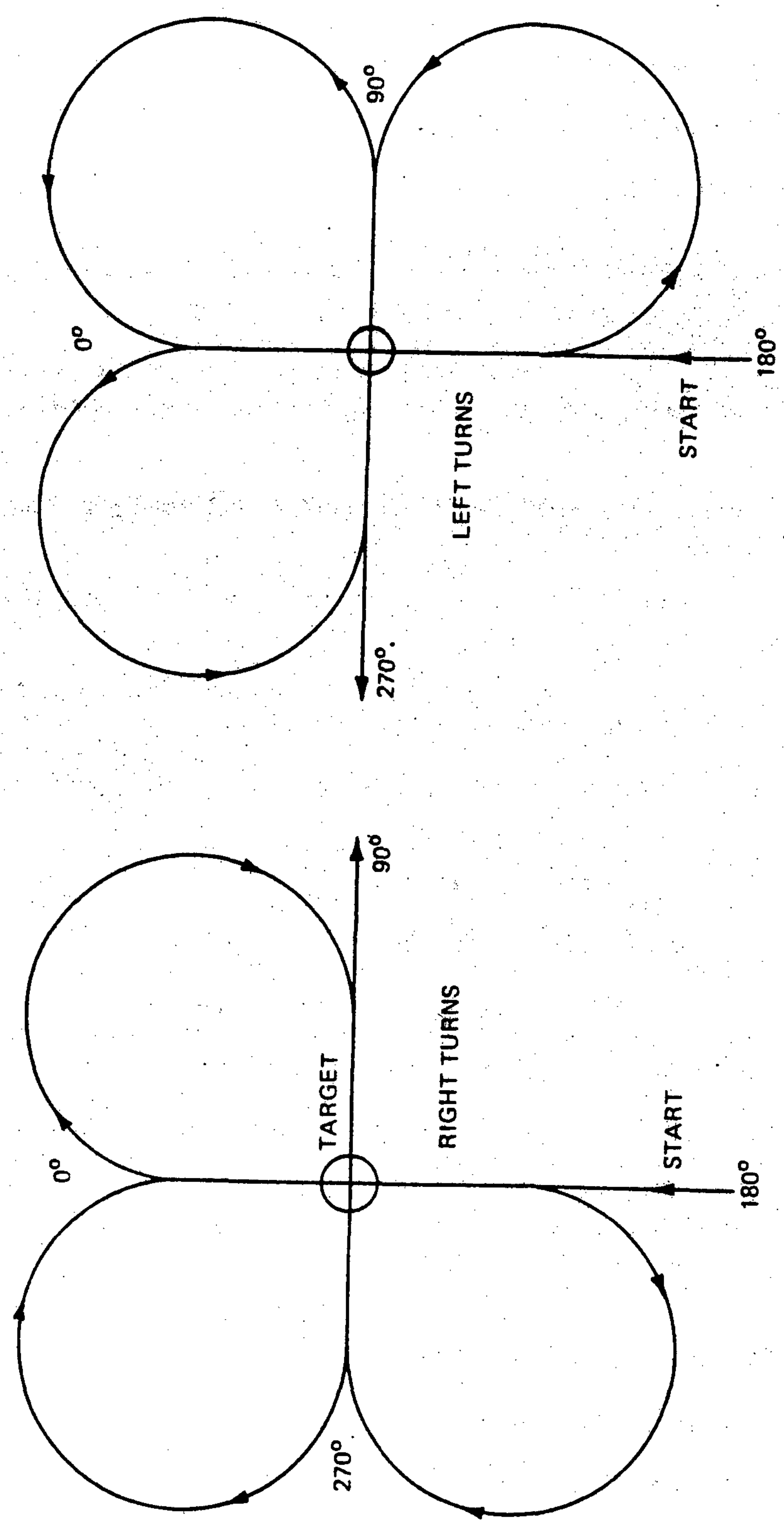

Figure 1. Flight pattern for compass air swing tests.

f. Record the following information:

(1) Altitude of aircraft.

(2) Time for each test run.

(3) Actual aircraft heading.

(4) Indicated heading.

(5) Aircraft roll and pitch.

5.9.3 Stable Platform Method - Preparation for Test

a. A test aircraft shall be equipped with a stable platform which, through telemetry, will indicate to the ground the true heading of the aircraft.

b. The pilot of the aircraft shall be briefed to familiarize him completely with the test objectives.

c. Practice flights shall be made to checkout the telemetry instrumentation.

d. The types of camera and film to be utilized shall be determined by personnel in the Photographic Laboratory Section.

e. The camera shall be properly installed and equipped with shock-mounts to minimize vibration effects.

5.9.4 Stable Platform Method - Conduct of Test

a. Repeat steps 5.9.3a and 5.9.3b.

b. Set up the camera so that the pictures taken of the instrument panel can be correlated (time-wise with the correct reference heading data telemetered from the stable platform to the ground station.

c. Energize the instrumentation (including photographic equipment) after stable flight has been established.

d. Record the following information:

(1) Altitude of aircraft.

(2) Time for each test run.

(3) Actual aircraft heading.

(4) Indicated heading.

6.0 DATA REQUIRED

6.1 Preparation for Test

Data to be recorded prior to testing will include but not be limited to:

a. Nomenclature serial number(s), and manufacturer's name of the test item.

b. Nomenclature serial number, accuracy tolerances, calibration requirements, and last calibration date of the electronic test equipment selected for the tests.

c. Results of pre-test inspection.

6.2 Test Conduct

Data to be recorded in addition to that listed below for each specific test shall include:

a. An engineering logbook containing, in chronological order, pertinent remarks and observations which would aid in a subsequent analysis of the test data. This information may consist of temperature, pressures, humidity, and other appropriate environmental data, or other description of equipment or components, and functions and deficiencies, as well as theoretical estimations, mathematical calculations, test conditions, intermittent or catastrophic failures, test parameters, etc., that were obtained during the test.

b. Instrumentation or measurement system mean error stated accuracy.

c. Test item sample size (number of measurement repetitions).

d. Photographs or motion pictures (black and white or color), sketches, diagrams, maps, charts, graphs, or other pictorial or graphic presentations which would support test results or conclusions.

6.2.1 Radio Frequency Interference Tests

Data shall be collected and recorded in accordance with MIL-STD-461, 462, and 463.

6.2.2 Low-Strength, Earth-Magnetic-Field Environment Tests

a. Record the excitation of the simulated azimuth detector.

b. Record the number of degrees of simulated azimuth detector oscillation on each side of null.

c. Record system's initial heading.

d. Record system's heading at 1-minute intervals until end of test.

6.2.3 Voltage and Frequency Variations Tests

a. Record voltage and frequency extremes.

b. Record each shift in synchronized null.

6.2.4 Erection Cycle and Accuracy Tests

a. Record gyroscope position and tolerances.

b. Record the average pitch and roll attitude excursions.

c. Record time of completion of erection.

6.2.5 Heading Drift Rate Tests

a. Record initial heading from precise angle indicator.

b. Record heading from precise angle indicator at 5-minute intervals for running time of 3 hours.

c. Record time of reading.

d. Record local latitude.

6.2.6 Vertical Drift Rate Tests

a. Record initial pitch and roll attidutes from precise angle indicator.

b. Record pitch and roll attitudes after a 15-minute interval.

c. Record time of reading.

d. Record local latitude.

6.2.7 Heading Precession Rate Tests

a. Record dc input to north and south latitude control circuits.

b. Record elapsed time of test.

c. Record rate of heading change from the precise angle indicator at beginning and end of test.

d. Record local latitude.

6.2.8 Compass Mode Accuracy Tests

a. Record azimuth detector latitude setting.

b. Record direction of rotation.

c. Record heading indicator readout.

6.2.9 Compass Ground Swing Accuracy Tests

a. Record MC-1, Compass Calibrator (or equivalent) readings for compass swing.

b. Record changes made to existing compass systems.

6.2.10 Compass Air Swing Tests

a. Record altitude of aircraft.

b. Record time for each test run.

c. Record actual aircraft heading.

d. Record indicated heading.

7.0 DATA REDUCTION AND PRESENTATION

Processing of raw test data shall, in general, consist of organizing, marking for identification and correlation, and grouping the test data according to test title.

Specific instructions for the reduction and presentation of individual test data are outlined in succeeding paragraphs.

7.1 Radio Frequency Interference Tests

Data collected in accordance with this test shall be reduced and presented as indicated in MIL-STD-461, 462, and 463.

7.2 Low-Strength, Earth-Magnetic-Field Environment Tests

System's heading versus time shall be presented in graphic form to allow comparison with applicable criteria.

7.3 Voltage and Frequency Variations Tests

Present, in tabular form, voltage and frequency extremes with shift in synchronized null.

7.4 Erection Cycle and Accuracy Tests

a. The pitch and roll excursions shall be averaged for 0 degrees, and 30 degrees tilt.

b. The average figure along with time for completion of erection shall be presented for comparison with the applicable criteria.

7.5 Heading Drift Rate Tests

b. The rate of heading change in degrees per hour shall be computed for each interval. These results shall be adjusted to obtain free drift rate by adding the earth's rate correction for the local latitude. (The earth's rate correction is $\pm$ 15 sine latitude degrees per hour for the Northern Hemisphere.)

b. The results shall be presented for comparison with the applicable criteria.

7.6 Vertical Drift Rate Tests

a. The pitch attitude readings shall be adjusted to obtain free drift rate by adding the earth's rate correction. (The earth's rate correction in pitch is + 15 cosine latitude sine H degrees per hour, where H is the heading of the gyroscope fore-aft axis with respect to geographic north. H = o degrees for north, 90 degrees for east.)

b. The roll attitude readings shall be adjusted to obtain free drift rate by adding the earth's rate correction. (The earth's rate correction in roll is - 15 cosine latitude sine H degrees per hour.)

b. The results shall be presented for comparison with the applicable criteria.

7.7 Heading Precession Rate Tests

a. The heading precession rate shall be computed by determining the rate of heading change during a given interval and correcting for the earth's rotation.

b. The results shall be presented for comparison with the applicable criteria.

7.8 Compass Mode Accuracy Tests

a. Azimuth detector heading versus heading indicator readout shall be presented in graphic form.

b. The results shall be presented for comparison with the applicable criteria.

7.9 Compass Ground Swing Tests

a. The data collected from the MC-1 calibrator shall be used to compare with other data as needed during the test.

b. If several ground swing accuracy tests have been conducted on a specific aircraft, then this data can be used for comparison between the ground swing accuracy tests to ascertain if proper installation and or changes to the installation have been made.

7.10 Compass Air Swing Tests

a. The photographs shall be analyzed by image interpretation personnel to obtain actual heading of the aircraft.

b. The data obtained shall be compared with the indicator readout photographs to determine the compass errors.

A written report shall accompany all of the above test data and shall consist of conclusions and recommendations drawn from test results. The test engineer's opinion, concerning the success or failure of any of the functions evaluated, shall be included. In addition, equipment specifications that will serve as the model for a comparison of the actual test results should be included.

Equipment evaluation usually will be limited to comparing the actual test results to the equipment specifications and the requirements as imposed by the intended usage. The results may also be compared to data gathered from previous test of similar equipment.

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